State of Rhode Island and Providence Plantations.

TWENTY-EIGHTH ANNUAL REPORT

OF THE

COMMISSIONERS OF INLAND FISHERIES,

MADE TO THE

GENERAL ASSEMBLY,

AT ITS

JANUARY SESSION, 1898.

PROVIDENCE:
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1898.

REPORT.

To the Honorable the General Assembly of the State of Rhode Island and Providence Plantations, at its January Session, 1898:

The Commissioners of Inland Fisheries herewith present their annual report for the year 1897.

It has been estimated by the United States Fish Commission that the fisheries industries of the State of Rhode Island represent an invested capital of over $1,000,000; yielding an annual income of more than $700,000, and furnishing employment to fifteen hundred people. An industry offering employment to so large a number of our citizens, and bringing, at the same time, large sums of money into the State, should be fostered with the utmost care; its condition should be critically examined; ample records should be kept; prejudicial factors should be detected; errors corrected; and active measures should be taken to still further develop what has been already so productive.

The statutes provide that the Commissioners of Inland Fisheries besides introducing, protecting and cultivating fish in the inland waters, shall have a general supervision of all matters relating to trespass upon any waters by fishermen not inhabitants of the State; of the abuses of seining privileges; of the observance of "close time;" and that the annual reports to the General Assembly shall contain such facts and suggestions as the commission may deem proper.

TROUT.

Pursuant with the above-mentioned provisions, the Commissioners during the past year (January, 1897—January, 1898) have purchased twenty thousand (20,000) yearling trout, and acknowledge the generous assistance received in the work of distribution from many fishermen of the State. Most gratifying reports have been received from fishermen during the past open season, and, though there have been a few complaints of illegal fishing, the better class of fishermen are strictly observing the law. The height of water in the streams promises a bountiful catch the coming year.

BLACK BASS.

Black bass fishing has not been satisfactory during the past season, and the Commission feels that its recent efforts and plans for the future in the direction of restocking the inland waters of the State were, and are, fully warranted.

An additional consignment of one thousand large-mouthed black bass has been received from the U. S. Commission, and the same has been deposited in the preserve set apart for the purpose of propagation of this species, near Westerly.

LAND LOCKED SALMON.

Out of three thousand eggs of this species received from the U. S. Commission, in January, the Commissioners have been successful in hatching upwards of two thousand. The young fish were reared until about four inches in length, and then deposited in Mill Brook, in the town of Charlestown. This stream was selected on account of its being the main feeder for Watchaug Lake, and it thus affords a nursery for the young salmon until they are old enough to take care of themselves in the larger body of water. These waters were stocked in May with the eggs of the fresh-water smelt, obtained from New Hampshire, it being necessary to introduce this variety of fish into the lake, as it is the natural food for the land locked salmon. It is the intention of the Com-

mission, pending the result of this experiment, to protect Mill Brook against all fishing. If this experiment is successful, other waters of the State may be similarly stocked.

The Commission again reports that certain sea fishes have been very abundant in Narragansett Bay and its tributaries.

COD.

The cod has been even more plentiful than in 1896, and has often been sold to the consumer for from two to five cents per pound.

MACKEREL.

Small mackerel have been quite plentiful in the upper waters of the bay, having been caught as far up the river as Crescent Park, something heretofore unknown to the oldest fisherman.

TAUTOG.

The early fishing was very good, fish weighing from ten to fifteen pounds being frequently caught.

SCUP.

Large quantities of scup have been caught in the traps in the lower part of the bay, though but few have been taken in the upper waters.

SQUITEAGUE.

The waters of the bay from Field's Point to Newport have abounded with these fish, specimens varying in weight from one to twelve pounds, rod and line fishermen have been afforded rare sport.

We are glad to note a growing interest in the fisheries, an interest that is becoming general all over the world. The progress that has been made in all other departments of industry has not been

absent in the fisheries, as the frequent conventions and other means of exchanging information prove. While the sale of salt water fish was formerly restricted to a narrow margin of the coast, the present facilities for packing and transporting enable those engaged in the business to distribute their goods, and markets are to be found in all parts of the country. This great extension of the area of distribution calls for a corresponding increase of supply that at times has taxed the ingenuity and resources of the fisherman to maintain. They have devised, and are using, improved appliances, without which it would be impossible to meet the very large and increasing demand, and there has naturally been some alarm lest the increase of fish caught should exhaust the ocean's supply. Efforts have been made to connect the large catches made by these new appliances with an alleged diminution of the fish, and complaints against the menhaden fishermen seining in the upper waters of the bay have been made to some of the Commissioners by residents along both shores. It is claimed that after the seiners have begun their work food fish are not so plentiful.

While in former reports we have pointed out other probable causes of fluctuation, we wish now to call attention to an additional natural cause that has received little or no attention. Long continued observation and great efforts have been made to learn the history and habits of the ocean fishes. It is known that some spawn in the ocean; others in the shallow salt water; still others in the upper waters of the streams. Now, if there has been a diminution of any of these fish, it is of the fresh water spawners. The kinds that show most notably a decrease are the bass, the shad, and the herring. If we look still further we shall see that the original spawning grounds of these species have been materially affected by the introduction of impurities and by the presence of obstructions. The impurities arise chiefly from the sewage of cities and manufacturer's waste, and will naturally be exceedingly difficult to correct. The obstructions are both artificial and natural. The artificial obstructions, such as dams, etc., may be corrected by the

adoption of fishways. The natural obstructions are often of a more serious nature. The sea frequently throws up a bar in estuaries and the mouths of streams in such a way as to prevent the fish from ascending into fresh water and depositing their spawn. Point Judith Pond offers an instance of this kind. The pond and its tributaries comprise the largest enclosed body of water in the State, being about four miles long and one mile and a half wide. In former years large numbers of bass and herring were found in the waters of this pond and in the streams opening into it. It was more than a breeding place, for large numbers of bass were found throughout the winter, though it is possible that they were accidentally shut in by the closing of the "breach." It is fair to infer that under favorable conditions fish would again make this their breeding ground.

Shipment of Fish and Lobsters by regular lines of Transportation from Newport, for the year 1897.

	Fish. Bbls.	Lobsters. Bbls.	Swordfish.
January	270	17	..
February	489	..	..
March	46	1	..
April	204	62	..
May	7,670	225	..
June	6,154	452	..
July	1,610	638	44
August	1,664	380	1
September	3,112	170	..
October	2,557	15	..
November	1,135	19	..
December	147	60	..
	25,058	2,039	45

Total of fish and lobsters, 27,097 barrels.

Table of Shipments by Old Colony Lines.

	Fish, Bbls.	Lobsters, Bbls.	Total.
1886			17,434
1887	16,657	834	17,491
1888	15,033	1,161	16,194
1889	19,306	2,047	21,353
1890	8,933	2,650	11,583
1891	18,032	2,204	20,236
1892	26,832	2,123	28,955
1893	24,452	1,399	25,851
1894	17,769	2,392	21,161
1895	24,622	2,119	26,741
1896	20,425	1,728	22,153
1897	20,900	1,959	22,859

The last year is for ten months, ending November 1st.

The following communication has been received by the Chairman of the Commission:

N. B. Church, Commission Merchant,

Agent for the U. S. Menhaden Oil and Guano Association, No. 153 Maiden Lane.

New York, January 3, 1898.

J. M. K. Southwick, Newport, R. I.

Dear Sir:—Replying to your favor of 1st. inst., I desire to say that I would like as usual to send you a full account of our Atlantic Coast fisheries, but fear that I have not kept the matter so fully in mind as usual. The mackerel fisheries began late in March, and was pursued with abundant catches until late in May when the fish disappeared, and were not seen in great quantities for the balance of the season. Shad and all other species of food fish have been very plentiful in their seasons on the whole coast north of Hatteras. Blue-fish, weak-fish, and scup especially so, in fact, so plentiful that it has not paid to catch them.

Menhaden have been very abundant in sections, and the catch runs higher than for several years. Although I have not the full statistics, I think the catch for the entire coast will exceed 600,000,000 fish, or 2,000,000 barrels.

There was a very large body of fish on the coast from Cape Cod to Eastport, Me., and large catches were made by those having factories there. A large body of these fish came into our bays in July and remained about forty days. Good catches were made by those running their factories, but most of the Rhode Island boats were in Maine, where the fish were fatter and more valuable. The Connecticut and New York boats had good fishing in Long Island Sound, Gardner's Bay and along the coast, and made excellent catches. In Delaware Bay, the fishing was as good as could be desired, and large catches were made by all the boats, and the same was true of the Chesapeake Bay and North Carolina coast. About 2,250,000 gallons of oil have been made, with 21,000 tons of dry fish scrap, and 35,000 tons of oiled fish scrap.

Trusting this may help you in making your report, I remain

Very truly yours,

N. B. CHURCH.

SCIENTIFIC WORK.

The past season there was added to this Commission a new member in the person of Professor H. C. Bumpus, and we have begun, under his direction, an investigation of the star-fish, a report of which is submitted herewith. We trust that this new departure in our work will meet with general approval, and be sustained by the State. May we not look forward to no very distant day when we shall have connected with the Commission a laboratory provided with all the necessary apparatus for the study of this and other cognate subjects, that have so important a bearing upon our fisheries?

The Lobster Hatchery, for reasons given in a former report not being in use for its original purpose, was loaned for the investigation of the star-fish, for which it has proved well adapted.

The Chairman, to whom the lobster hatching experiment was intrusted, would respectfully recommend that the property acquired by him for that purpose, together with such sums of money as remain unexpended, be turned over to the Inland Fisheries Commissioners, to be used by them for the purpose of the Commission.

The receipts and disbursements of the Commission have been as follows:

State of Rhode Island in account with Commissioners of Inland Fisheries:

1896.	Dr.	
Dec. 31.	To balance due Commissioners	$203 71
1897.		
Oct. 1.	To paid for 20,000 yearling trout	717 60
Dec. 9.	" " 12 transporting cans	27 00
Dec. 31.	" " expenses, Commissioners	310 07
Dec. 31.	" " printing and postage	21 30
		$1,279 68

1897.	Cr.	
Jan. 29.	By cash of State Treasurer	$203 71
Oct. 5.	" " "	753 12
Dec. 31.	By balance due Commissioners	322 85
		$1,279 68

J. M. K. SOUTHWICK,
HENRY T. ROOT,
CHAS. W. WILLARD,
WM. P. MORTON,
ADELBERT D. ROBERTS,
HERMON C. BUMPUS,

Commissioners of Inland Fisheries.

REPORT OF THE BIOLOGIST

OF THE

COMMISSION OF INLAND FISHERIES.

Many problems of economic interest have been suggested to the members of the Commission as worthy of careful scientific investigation, but one in particular—the depredations of the star-fish—is of such pressing importance that the Commission has recommended its immediate consideration.

Interviews with our fishermen reveal lack of definite information in regard to the habits of the animal, and reference to the literature on the subject yields little of practical value.

The facts before us are as follows:

The natural equilibrium of life in Narragansett Bay has been disturbed; many of the fish which once inhabited our waters have been destroyed; and their place has been taken by new forms; the rivers and streams opening into the bay are now more or less polluted, and are no longer fit breeding places; of recent years the oyster men have cleared and planted large tracts of our shallow inlets, and have thus not only imported millions of oysters but with these, and quite unintentionally, myriads of animals quite new to this locality. In addition to animals quite new to the locality, animals already here have been often emancipated by the destruction of their natural enemies, and have consequently multiplied without restraint. The star-fish belongs to this latter class. It has destroyed many of the large beds of mussels, the attractive feature of our bay for many of the most important food fishes, it

has materially assisted in the destruction of the clam, it has reduced the quahaug catch, and would exterminate the oyster were it not for the eternal vigilance of the oyster-men.

In view of the above fact it is remarkable that no one has attempted to determine the methods of life of the star-fish, with the hope of discovering some period of its existence when it can be more easily captured and killed than by the present methods, or of some natural enemy which might destroy the pest without the toil of the fisherman, or of some plan of enclosure which might restrict if not prevent its inroads. A knowledge of the life history of various insects has enabled the agriculturist to prevent their ravages. The understanding of the life habits of bacteria has revolutionized the methods of surgery and medicine. The first step in the campaign against any enemy should be a determination of the characters of the enemy itself.

That this study might be undertaken without delay, my colleagues on the Commission very kindly relinquished a generous part of the appropriation made to them for their expenses, and the Chairman, Hon. J. M. K. Southwick, placed at my disposal the house-boat and car which he had used in connection with his work on the lobster. This floating laboratory was placed at the mouth of the Kickemuit river, immediately over one of the most valuable oyster beds in the bay. It was fully equipped with instruments, microscopes, chemicals, glassware, etc., by the Anatomical Laboratory of Brown University. Dr. A. D. Mead was placed in charge, and certain questions were given him for solution. It will be noted below that many of the questions must, from their nature, remain unanswered until observations have been extended throughout the entire year, and it is probable that two or three years, or even a longer time, will be necessary for the final clearing up of questions of rate of growth, time of sexual maturity, etc. Those who have undertaken similar lines of research know that really valuable results can be secured only through patience and protracted investigation—one well established fact is worth more than a thousand fancies.

The questions are arranged in four groups: the first dealing with the identification and distribution of the star-fish; the second, with the mode of life; the third, with the breeding habits, and the fourth, with natural and artificial means of destruction. The answers, so far as they have been determined, appear in the second part of this report.

INDENTIFICATION AND DISTRIBUTION.

I. Does the animal, known to our fishermen as the star-fish or five-finger, belong to one or several species? (It is evident that, if there are two or more species, artificial or natural agents destructive to one may prove quite harmless to the others.)

II. What is the geographical and bathymetrical distribution? (The reply to these questions will indicate the areas subject to or most liable to invasion.)

MODE OF LIFE.

III. What is the method of locomotion? (It is possible that some barrier might be arranged that would limit, if not prevent, invasion.)

IV. Are the star-fish, which are reputed to appear in schools, in any way different from those known to occur naturally in a particular locality?

V. To or from what distances may star-fish migrate?

VI. What animals are devoured by the star-fish for food? (If the young star-fish feed habitually upon certain animals, it is possible that the destruction of the latter will cause the former to perish.)

VII. What is the method of feeding?

VIII. How rapidly may a star-fish devour oysters?

THE BREEDING HABITS.

IX. At which season of the year do the star-fish spawn? (If at a particular season, a special effort should be made to kill the

animals before spawning, and thus destroy both stars and spawn.)

X. What are the habits of the "fry" or free swimming young? (The young of many marine animals, while far more abundant than the adults, are far more delicate and easier of extermination.)

XI. What is the duration of the larval period? (If an effort is to be made to destroy the larvæ, when must it be made?)

XII. What are the habits of the young star-fish? (It is possible that the young star-fish, like the young of many fish, tend to gather in schools. If so, the young might be killed off in thousands.)

XIII. What is the rate of growth up to sexual maturity?

XIV. What is the size and age at sexual maturity?

NATURAL AND ARTIFICIAL MEANS OF DESTRUCTION.

XV. What are the natural enemies of the star-fish?

XVI. Is the popular idea that the dismembered fragments of a star-fish will regenerate new star-fish founded on fact?

XVII. What are the artificial methods of destruction now in use in Rhode Island or elsewhere?

IDENTIFICATION AND DISTRIBUTION.

I. *Does the animal, known to our fishermen as the star-fish or five-finger, belong to one or several species? (It is evident that, if there are two or more species, artificial or natural agents destructive to one may prove quite harmless to the others).*

In a description of the star-fishes of the world W. Percy Sladen recognizes 810 species of these animals, nearly 100 of which are found only in very deep water—below 500 fathoms—and at a depth of even 2,900 fathoms. Several species are found in the waters of Narragansett Bay:—

The common star-fish (Asterias Forbesii).
The purple star-fish (Asterias vulgaris).
The blood star-fish (Cribrella sanguinolenta).
The snake star-fish (Ophiopholis aculeata).

The first species is extremely abundant and is altogether too well known from its depredations on the mussel and oyster beds. The closely related purple star-fish is certainly very rare, at least from Rocky Point north. Among the thousands of stars examined from the oyster beds at Rocky Point, Kickemuit river, and other localities, I have never seen a single specimen. It is, however, common at Newport. If it were as abundant as the common five-finger it doubtless would be equally destructive to the oyster and mussel. The purple star-fish can usually be readily distinguished from the more common species. It has a purple or sometimes reddish color, and a softer, less rigid skeleton, and the arms are more tapering. Other characters, for example the shape of the minute forceps (pedicellaria) which are found among the spines on the whole upper surface of the body, are of more technical value in the determination of species.

The examination of a large number of specimens of the common star-fish, and of the related purple star, shows that there is a great deal of variation among the individuals of the same species with regard to color, shape of the arms, and size and number of spines. These variations are so great that the French naturalist, Perrier, made five distinct species of Asterias to include those star-fish along our coast, which, according to the American naturalists, L. Agassiz, Stimpson, and Verrill, belong to only two species. The fact remains, however, that the star-fish of either species vary greatly in form and color. The young stars whose arms are less than one-half inch in length show the same variation as are seen in the adults. It would be interesting from a biological point of view to determine whether these variarions are due to sex, to surrounding conditions,—food, density of the water, etc.,—or whether they are casual individual differences.

The small blood star-fish, Cribrella, could not easily be mistaken for either of the preceding species. It is bright red, with round, smooth, tapering arms. These stars are found occasionally upon the oyster beds, and several were taken during the dredging excursion from Brown University, in the spring of 1897.

Several specimens of the small snake star-fish, Ophiopholis, were taken at the same time, and it is probable that other species will be discovered.

II. *What is the geographical and bathymetrical distribution?* (*The reply to these questions will indicate the area subject to or most liable to invasion.*)

In answering this and the following questions reference is made only to the first two species of star-fish, unless otherwise stated.

Geographical distribution. The purple star ranges from Labrador (probably further north) to Cape Hatteras. It is very abundant on the coast of Maine and becomes less common, or even rare, on the southern coast of New England. It is common at Wood's Holl, Mass., but not so abundant as the other species.

The common star is distributed from Maine to the Gulf of Mexico. Unlike the purple star it is comparatively rare north of Cape Cod, but is the most abundant species in the southern waters of New England. The two species, therefore, overlap each other in their geographical distribution, though the purple star is the northern, and the common star the southern species.

Bathymetrical distribution. The purple star is found from high water mark to 208 fathoms, while the common star (Asterias Forbesii) has a more limited distribution, viz.: from high water to twenty fathoms. The star-fish of both species often remain among the rocks or in the seaweed after the tide has ebbed.

MODE OF LIFE.

III. *What is the method of locomotion?* (*It is possible that some barrier might be arranged that would limit, if not prevent, invasion.*)

The furrow on the under side of each arm is furnished with four rows of closely set "suckers" (ambulacral feet). Each of these hollow cylindrical feet can be extended or retracted at will, and is provided with an actual sucker which will hold to almost any surface.

By means of these ambulacral feet the animal walks or crawls. The progress is slow, it is true, but sure, for there is no slipping, and in a few hours a surprisingly long distance can be covered. The feet are so numerous, and the movement so even, that the animal seems rather to glide than to crawl. Moreover the sea-water buoys up the star-fish so that it does not have its weight to support. The star-fish will move easily up the smooth surface of a vertical glass plate or along the underside of a horizontal plane. I have often seen small stars, measuring about three-eighths of an inch from centre to tip of arm, crawl up the side of the aquarium and then glide along the surface of the water. During this performance the star is always on its back, and the suckers extend to the surface of the water.

The buoyancy of the water and the great number of feet enable the animal to move over the lightest silt as well as over hard surfaces. Even large star-fish are able to pass through very narrow and irregular crevices, for the skeleton is composed of innumerable small plates, joined together, and provided with muscles which allows the body to adapt itself to the shape of the crevice. The star-fish, unlike many other marine animals, snails, worms, etc., will never creep out of the sea-water, nor even protrude an arm above the surface. It will never cross a barrier that extends even a little above the surface of the water.

The star-fish is generally believed by fishermen to have a much more active mode of locomotion than that of crawling. The tradition is that large numbers of stars cling together to form a compact ball from a foot to three feet or more in diameter, which is rolled along the bottom by the tide until, striking an oyster bed, the ball goes to pieces and the stars begin work at once. It is difficult to find an actual eye witness of this phenomenon, though Ernest Ingersoll tells of an old oysterman, "Captain Eaton, of New Haven, who said that he and his brother once raked up the end of a cylindrical roll of star-fishes clinging tightly together, which they hauled into their boat until it would contain no more, when they had to break the roll or 'string,' as he called

it, which was a foot or more in diameter." The "string" was composed only of star-fishes.

I have never observed anything to confirm in the slightest degree the truth of these stories, though I have seen balls of star-fish clinging to each other. Upon examination it was evident that the stars were all endeavoring to devour some animal held in their midst.

It is difficult to conceive of a barrier which would be practical and efficient in keeping the stars off the oyster bed. The animals can creep over any surface and through small crevices provided they are under water. Theoretically a fine netting across the inlet of an estuary or surrounding the beds, and extending from the surface of high water to the bottom, would keep out the larger stars; or if the oysters were suspended from floats and kept off the bottom the stars could not readily reach them. Neither of these contrivances would, of course, keep off the young stars which for the first two or three weeks of their existence swim about freely in the water.

IV. *Are the star-fish which are reputed to appear in schools in any way different from those known to occur naturally in a particular locality?*

I have thus far not had an opportunity to examine the star-fish reported to appear in schools.

V. *To or from what distance may star-fish migrate?*

I have not yet made experiments to determine.

VI. *What animals are devoured by the star-fish for Food?* (*If the young star-fish feed habitually upon certain animals, it is possible that the destruction of the latter will cause the former to perish.*)

The young star-fish are exceedingly voracious, perhaps more so than the older ones. They find an abundance of food among the myriads of small animals of various kinds which live among rocks

covered with sea-weed or in the eel-grass along the muddy shore. In the eel-grass, just below low water mark, the small stars (half-inch more or less from centre to tip) are especially numerous, and here they will be found devouring small clams, quahaugs, sea-snails, and worms of various kinds. The eel-grass is usually abundant near oyster beds and is a veritable nursery for young star-fish. In the aquarium they eagerly devour fragments of crabs or other animals, and occasionally even other star-fish smaller than themselves. The adult star-fish, besides eating numerous small animals which come in its way, attacks and devours larger ones. I have seen them eat the sea-snails Litorina, Ilyanassa, Urosalpinx, barnacles, quahaugs, mussels, as well as oysters. There seems to be no question, however, but that they prefer small oysters to any other diet. If hungry they will also devour other star-fish which are smaller or which have been mutilated.

But we must give the animal his due, and the star-fish should be given the credit of devouring in great numbers, "oyster-drills" of various species, including young "conchs" (Sycotypus and Fulgar), which in southern waters, especially in the Chesapeake Bay and in other countries, for example Japan, where the star-fish are not so common, prove a serious menace to the oyster culture.

VII. *What is the method of feeding?*

The mouth of the star-fish is in the centre of the disc on the lower side of the body. Comparatively small pieces of food are taken into the stomach and the refuse ejected again through the mouth. But, since the mouth is small (no more than one-fourth inch in a good-sized star), and surrounded by a rigid skeleton, larger animals, which form the greater part of the star-fish bill-of-fare, are necessarily digested without being taken in through the mouth. The stomach, therefore, is turned inside out and, wrapping itself about the animal to be devoured, digests gests it where it lies. It is safe to say, I think, that the stomach

can be protruded for a distance equal to the length of the star-fish's arm. Having digested the food the stomach is withdrawn to its normal position within the body.

Most of the animals upon which the star-fish prey are molluscs protected by hard shells; for example, the sea-snails, mussels, quahaugs, and oysters. How does the star get at the soft part of the molluscs? This question has given rise to a great deal of interesting, not to say amusing, speculation, especially with respect to the oyster.

An old tradition in England and this country is to the effect that the star-fish takes the oyster by surprise and puts an arm into its gaping shell; then a fight ensues. Sometimes the oyster is victorious while the star-fish retreats minus an arm, but often the oyster succumbs, since it cannot live long with its shell open, and the star then devours its prey at leisure. There are two facts that are sufficient to disprove this theory. In the first place, the oyster is very sensitive and feels the slightest disturbance in the vicinity of the margin of the open shell. In the second place, the shell does not open wide enough to admit the arm of the star. Moreover, simple observation of the star-fish during the process of eating disproves the story.

It is supposed by many that the star-fish secrets a poison into the shell which causes the latter to open. But the valves of the shell can be shut water tight and would exclude such a poison. I have taken away from the star-fish oysters, muscles, and drills which had already been opened, and placed them in an aquarium where they soon recovered and behaved as though nothing had happened. Schiemenz found the same to be true in the case of the quahaug (Venus).

Some have supposed that the star bores a hole through the shell of the victim, but the star has no boring apparatus, and the shells known to be opened by the star have no holes in them.

It is a very common belief that an acid is secreted by the star which dissolves the shell so that an entrance is effected. After a successful opening, however, the litmus-paper shows no acid from

the stomach of the star-fish, and the margin of the shells shows no trace of having been acted upon by an acid. A considerable quantity of acid would be required to sufficiently dissolve the shell of a medium sized oyster, and this would undoubtedly dissolve, at the same time, the unprotected calcareous spines about the mouth of the star-fish itself.

The most prevalent opinion is, perhaps, that the star-fish chips away the thin edges of the shell until an entrance is gained to the soft parts. The broken edges of the oyster shells which have been opened by the star seem at first to sustain this opinion. The process is thus described in a recent number of a Providence newspaper. "The star-fish seizes its prey by clasping its tentacles around the soft, fringy edge of the oyster, which it eats away until the soft oyster can be sucked from the orifice, etc." Ingersoll, in an article on Oyster Industry, already referred to, after speaking of the alleged use of acid in opening the shell, says:—"Moreover, it seems unnecessary, since the appearance of every shell attacked at once suggests the breaking down, chipping off movement, which the star-fish might easily produce by seizing and suddenly pulling down with the suckers nearest the mouth, or by a contraction of the elastic opening of the stomach. At any rate the thin edge of the shell is broken away until an entrance is made which the oyster has no way of barricading."

An oyster which has not been injured by rough treatment has the edges of the shell extremely thin and so fragile that they can be broken down with a camel's hair brush. The lower shell is particularly fragile near the edge. It will be noticed, however, that the valves frequently do not come together at all at the extreme edge, and the real line of contact, the biting edge, is one-fourth inch or more further back. The chipping of the margin of the shell by the star-fish is merely accidental, and avails nothing in getting at the soft parts of the oyster. I have carefully examined a large number of shells of oysters known to have been devoured by star-fish, and, though they appear to be badly chipped, the biting edge is never broken, and the shells have always been

found to be water tight. If such a shell, recently opened by the star, be filled with water, and the valves held between the thumb and the finger, the water will not leak out even though the shell be violently shaken.

In mussels which have been opened by the star-fish there is no trace of any chipping at all. The reason is plain: the valves of the shell come together firmly at the very edge; there is no delicate fringe at the margin. The same is, of course, true of the quahaug. Nevertheless the quahaug and mussel are readily opened by the star-fish. It follows, therefore, that if the star-fish gained entrance to the soft oyster by chipping off the edge of the shell, a different process must be adopted in entering a mussel or quahaug, to say nothing of the snails which it also devours.

The credit of solving the problem—How do the star-fish open oysters?—is due to Dr. Paulus Schiemenz, of Hanover, Germany, who carried on his investigations at the famous Zoölogical Station at Naples. The problem was suggested to him by Collins' report of the enormous injury done to the oyster beds by the star-fish in Long Island Sound. The process is briefly as follows:—The star-fish so covers his victim that the suckers on the under side of the arms are distributed part to one valve, part to the other, and the remainder frequently to some surrounding object. (In the case of the snails the suckers are attached to the operculum and to the shell). The suckers are very numerous and stick fast, and a tendency to straighten the arms results in a constant pull upon the shells in opposite directions, which, if strong enough, would open the shells. It is true that a star-fish is not strong enough to open an oyster or quahaug immediately in this manner, but he can and does fatigue his prey. The constant, steady pull in opposite directions soon fatigues the muscle which holds the shell together, and the oyster or clam presently gapes open. The oyster can overcome the strong pull for a short time but not a weaker pull for a long time. The same principle is well illustrated in the case of the periwinkle or conch. If a string be tied around the "foot" so as to give a good hold on the animal, a strong man can-

not pull the mollusc out of its shell, but if it be suspended by this string it cannot sustain for a long time even its own weight. On the same principle a man who can hold at arm's length a weight of twenty pounds cannot hold his empty hand in this position for ten minutes. Schiemenz showed by experiment that the star could exert a pull of over 1,200 grams, and that a pull of 900 grams is sufficient for opening a good size quahaug if allowed to act for thirty minutes.

My own observations and experiments are entirely in accord with Schiemenz's results.

Frequently more than one star-fish takes part in opening an oyster, and once an oyster is opened other star-fish often happen along and enter into the feast. It is the young oysters that are in greatest danger from the stars, and the danger decreases as the oysters grow larger. Oysters of marketable size, that is, three or four years old, are comparatively unmolested. Of course, the larger star-fish can open the larger oysters, but fortunately the larger stars are more easily caught in the "mops" and thus more easily kept off the beds. It has not been ascertained how large an oyster can be opened by the star-fish.

VIII. *How rapidly may a star-fish devour oysters?*

The answer to this question depends upon several conditions, viz.:—the size of the stars and of the oysters, the temperature of the water, and the hunger of the star-fish. I cannot at present give a very satisfactory answer. Collectively the star-fish devour an enormous number of oysters in a few days. A Providence oysterman informs me that a few years ago, during a few days when his engines were being repaired, so that he could not "mop" the stars, the latter completely destroyed a whole bed (several acres of seed oysters) leaving hardly an oyster alive.

Collins (Notes on the Oyster Fishery of Connecticut) estimates that in 1888 the damage done to the beds in the Connecticut waters alone was $631,500, in spite of the fact that 42,000 bushels of stars were taken from the beds that same year.

IX. *At which season of the year do the star-fish spawn?* (*If at a particular season, a special effort should be made to kill the animals before spawning, and thus destroy both stars and spawn.*)

The spawning season of the star-fish is undetermined. That they spawn in the summer any oyster-man will tell you. I have found stars containing ripe eggs and ripe spermatozoa from June until December, and should not be surprised if they spawned throughout the year.

X. *What are the habits of the "fry" or free swimming young?* (*The young of many marine animals, while far more abundant than the adults, are far more delicate and easier of extermination.*)

I have thus far given little attention to the habits of the free-swimming "fry" or brachiolaria. It is well-known, however, that they begin life in the water, that is to say, the female star-fish discharges the eggs unprotected into the water, and the milt or spermatozoa, discharged in the same way by the male, comes in contact with and fertilizes the eggs. In a few hours the eggs have developed into free-swimming forms which propel themselves by means of vibratile hairs definitely arranged on the surface.

Under favorable conditions one can capture millions of these little creatures by dragging a fine net at the surface of the water. They appear and disappear mysteriously however, usually preferring to come to the surface at night. Menhaden and other marine animals, not the least of them the oyster itself, doubtless destroy millions of these minute larvæ.

XI. *What is the duration of the larval period?* (*If an effort is to be made to destroy the larvæ, when must it be made?*)

The duration of the larval period is about three weeks, but varies according to the temperature of the water, an increase in temperature accelerating development.

XII. *What are the habits of the young star-fish?* (*It is possible that the young star-fish, like the young of many fish, tend to gather in schools. If so, the young might be killed off in thousands.*)

I have mentioned some of the habits of the young stars under the previous heading. There is little doubt that if the eel-grass were cleared out they would be destroyed in great numbers.

XIII. *What is the rate of growth up to sexual maturity?*

As far as I am aware this is not known. By arranging the star-fish according to size Mr. Agassiz has estimated roughly that it takes about fourteen years to reach full development, but that they may become sexually matured in about six years. I have been unfortunate in losing many of the specimens which I had under observation.

XIV. *What is the size and age at sexual maturity?*

I have made and tabulated some observations to determine the size of the star when it first begins to breed, and believe that it does not reach maturity until it measures two inches from the mouth to tip of arm, and rarely until it is even larger. This conclusion must necessarily be provisional.

XV. *What are the natural enemies of the star-fish?*

Fresh water and extreme cold are most effective in killing off star-fish. Heavy rain storms and freshets so freshen the water in estuaries and shallow bays that great numbers of stars are killed, though the oysters are not harmed. The freshet of March, 1888, practically annihilated the stars on the extensive oyster beds in Kickemuit river, as I am told by the proprietor, and they were not again a serious menace till three or four years later. I have started some experiments to ascertain the least density of water compatible with the life of the star.

The free-swimming "fry" of the star-fish fall prey to many

fishes and other animals which feed indiscriminately upon minute pelagic forms. It is not well understood what the enemies of the adult star may be. An oysterman told me that he had seen gulls carrying them off, and with field glasses had watched them. It is possible that crows also prey upon the stars that are left on the beach after the tide has ebbed. The crows in some regions of our coast make daily journeys from their rookeries to the shore, and as many as two hundred and thirty-six were one day counted on the west shore of Portsmouth, R. I.

I have noticed on certain lots of star-fish, dredged from different localities, what appears to be a disease, attacking the skin first and not infrequently eating its way through the body. This disease attacks both the common star and the purple star. Some of the star-fish in my cars at Kickemuit river were so seriously affected that some of the arms were entirely eaten through and the ends dropped off. Later some of them recovered.

The most destructive enemies of many animals are the parasites, and if this disease, to which I have just referred, proves to be due to a bacterium or some other infectious parasite, it may be of service in destroying the star-fish, and thus directly protecting the mussels, clams, and oysters. There seems to be no doubt but that, with the development of the oyster beds, the star-fish has become more numerous along our New England coast.

XVI. *Is the popular idea that the dismembered fragments of a star-fish will regenerate new star-fish, founded on fact?*

It is certainly a most popular opinion that if the star-fish be cut in several pieces each fragment may regenerate the remaining parts so that a new animal results. Ingersoll (Oyster Industry of the United States) says:—"When oysters were first cultivated along the American coast, and this enemy first became known, the oystermen used to save all that they caught in their tongs and dredges, and pile them up in a corner of their boats until evening. Then they would collect them in small packages and draw a cord around each lot tightly enough to cut through it.

This done, the remnants were cast overboard and considered done for. But this was entirely a mistake, as was presently found out. Five or six of these fragments not only retained life but renewed the lost parts and became active again. Thus, instead of diminishing the pest these men were directly increasing it, since they were making two or three star-fishes out of each captive. It was a case of multiplication by division, which may be an invariable paradox in mathematics but is by no means one in zoölogy."

I have made some experiments in order to find out what the actual powers of regeneration are. If the arm of a star be mangled it will generally drop off, or can easily be pulled off, always severing its connection with the central disc at a certain fixed line. If these stars be kept in a suitable car they will renew the lost arms. If an arm be cut off at some distance from the disc it will regenerate a new tip. Double or rather forked arms were produced by cutting off the tip of an arm and splitting the stump. Each half stump, so to speak, regenerated a complete tip. Such freaks are sometimes found among the stars which come up in the dredge or mop.

Four of the five arms were taken off at the same time, and all four regenerated. The arms which were removed, however, never showed the slightest sign of regenerating the rest of the star-fish. Another experiment, I cut the star-fishes into two parts, one having three arms and the greater part of the central disc, the other having two arms and the smaller part of the disc. The smaller part in each case died, while the larger lived. All but one of these specimens were afterwards destroyed by other star-fishes in the aquarium. One still survives and has lived for months in the same aquarium with the stars which have, meantime, regenerated their lost arms. This one, however, has not showed the slightest sign of regenerating its lost parts, nor had the others before they were killed.

More experiments must, of course, be made before a definite conclusion can be reached, but I believe that the popular opinion that two star-fish may be gotten from one, by cutting it up and allowing the fragments to regenerate, is erroneous ; that only one

complete star can result from all the fragments, and then only when one fragment contains at least the whole central disc. Complete regeneration from a single arm has been described for certain species by Prof. Haeckel.

XVII. *What are the artificial methods of destruction now in use in Rhode Island or elsewhere?*

Star-fishes are caught in considerable numbers with the spear and tongs, but the more efficient method is the use of the "tangle" or "mop." The tangle consists of a number of mops of cotton waste or similar material attached to an iron bar. By dragging these mops over the oyster beds the stars become entangled and are drawn up with the mops. The mops are usually detached from the iron bar and thrown, together with the stars, into a tub of hot water. Meanwhile other mops are attached to the bar and thrown overboard. After the stars are killed they can be more easily picked off the mops than when they are alive. Some oystermen prefer to dredge up oysters, stars and all, and, having culled out the stars, to replant the oysters. Dead stars make an excellent fertilizer.

APPLICATION FOR APPROPRIATION.

The Commission respectfully asks for an appropriation of $3,000 to defray the expenses of the ensuing year, and bases its application upon the following:

1. The investigation upon the depredations of the star-fish, an account of which accompanies this application, have already yielded sufficient scientific and practical results to warrant their continuation for at least an entire year, that the period of breeding, rate of growth, and seasonal habits may be definitely determined.

2. The reasons for the present depleted conditions of the clam-beds should be known. The breeding habits and breeding period

of the clam should be ascertained, and the feasibility of artificially restocking portions of the shore should be tested. There is here an imperative demand made upon the Commission to rehabilitate a waning industry.

3. The statutes provide that the Commission "shall from time to time examine all the weirs, traps, and other contrivances, with the view of carrying out such regulations as are most beneficial to the people of the State." At the present time the State has no information as to the number, location or ownership of the fish traps, and is keeping no adequate record of the amount of fish caught, or of the amount consumed within the State, or shipped into other States. With the assistance of the fishermen of Rhode Island it has planned to keep a record of the location and ownership of the fish-traps, and to jealously guard our interests against the invasion of those who are not inhabitants of the State.

4. It is the purpose of the Commission to examine into the breeding habits of the food fishes, and to endeavor to induce the shad, and the salmon, to again return to our waters.

5. Your Commissioners are faithfully endeavoring to preserve to the State an industry which has yielded many millions of dollars in the past, and which, if intelligently administered, will continue to be one of its richest possessions. The members of the Commission are serving without salary, and they only ask for sufficient funds to protect and advance the affairs of the fisheries in accordance with the interests and economy of the State.